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Filed	:	6 JUNE 1997
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Registrateur van Patente
Registrar of Patents

SPOOR AND FISHER

REPUBLIC OF SOUTH AFRICA

PATENTS ACT, 1978

FORM P.1

APPLICATION FOR A PATENT

AND ACKNOWLEDGEMENT OF RECEIPT

(Section 30 (1) - Regulation 22)

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The granting of a patent is hereby requested by the undermentioned applicant on the basis of the present application filed in duplicate

OFFICIAL APPLICATION NO.			S AND F REFERENCE
21	01	975022	JP/S 1212

FULL NAME(S) OF APPLICANT(S)

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TITLE OF INVENTION

54	METHOD OF OPERATION OF A MULTI-STATION NETWORK

THE APPLICANT CLAIMS PRIORITY AS SET OUT ON THE ACCOMPANYING FORM P.2. THE EARLIEST PRIORITY CLAIMED IS:

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~~THIS APPLICATION IS FOR A PATENT OF ADDITION TO PATENT APPLICATION NO.~~

21	01	

~~THIS APPLICATION IS A FRESH APPLICATION IN TERMS OF SECTION 37 AND IS BASED ON APPLICATION NO.~~

21	01	

THIS APPLICATION IS ACCOMPANIED BY:

- [x] 1. A single copy of a provisional ~~or two copies of a complete~~ specification of 20 pages.
- [x] 2. Drawings of 2 sheets.
- [ ] 3. Publication particulars and abstract (Form P.8 in duplicate).
- [ ] 4. A copy of Figure .... of the drawings (if any) for the abstract.
- [ ] 5. An assignment of invention.
- [ ] 6. Certified priority document(s).
- [ ] 7. Translation of the priority document(s).
- [ ] 8. An assignment of priority rights.
- [ ] 9. A copy of the Form P.2. and the specification of S.A. Patent Application No.
- [ ] 10. A declaration and power of attorney on Form P.3.
- [ ] 11. Request for ante-dating on Form P.4.
- [ ] 12. Request for classification on Form P.9.
- [x] 13. Form P.2 in duplicate.

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Dated: 6 JUNE 1997

SPOOR AND FISHER

PATENT ATTORNEYS FOR THE APPLICANT(S)

REGISTRAR OF PATENTS, DESIGNS, TRADE MARKS AND COPYRIGHT

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PRETORIA

REGISTRATEUR VAN PATENTE, MODELLE, HANDELSMERKE EN OUTEURSREG

REGISTRAR OF PATENTS

REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978

PROVISIONAL SPECIFICATION

(Section 30(1) - Regulation 27)

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FULL NAME(S) OF APPLICANT(S)

71	SALBU RESEARCH AND DEVELOPMENT (PROPRIETARY) LIMITED

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TITLE OF INVENTION

54	METHOD OF OPERATION OF A MULTI-STATION NETWORK

BACKGROUND OF THE INVENTION

THIS invention relates to a method of operating a multi-station communication network.

International patent application no. PCT/GB 95/02972 describes a communication network in which individual stations in the network can send messages to other stations by using intermediate stations to relay the message data in an opportunistic manner.

In order to be in a position to send a new message out into the network via a selected one of several possible intermediate stations, or to relay a message onward in the same manner, each station must at any time normally be in contact with several other stations.

To optimise the operation of a network of this kind, the interaction of the individual stations must be regulated according to predetermined criteria, in order to minimise contention or interference between stations while at the same time maximising data throughput at minimum transmission power.

It is an object of the invention to provide a method of operating a multi-station communication network which regulates the connectivity between stations in order to optimise the operation of the network.

SUMMARY OF THE INVENTION

According to the inventing there is provided a method of operating a communication network comprising a plurality of stations each able to transmit and receive data so that the network can transmit data from an originating station to a destination station via at least one intermediate station, the method comprising:

a) defining a plurality of calling channels, each calling channel except a first having a higher data capacity than a previous calling channel;

b) selecting, at each station and according to first predetermined criteria, a calling channel for the transmission of probe signals to other stations;

c) transmitting probe signals from each station on the selected calling channel, other stations which receive the probe signals responding by transmitting reply signals to the probing station, thereby indicating to the probing stations their availability as destination or intermediate stations;

d) comparing the number of reply signals received from different stations with a predetermined number;

e) selecting a different calling channel having a different data rate from the previously selected calling channel according to second predetermined criteria if the number of reply signals

does not correspond to the predetermined number; and

f) repeating steps (c) to (e) until the number of reply signals received by the probing station corresponds to the predetermined number.

The first predetermined criteria may include the calling channel data rate and/or the calling channel transmission power, the calling channel being selected according to the highest available channel data rate and the lowest available channel transmission power.

The second predetermined criteria may also include the calling channel data rate and/or the calling channel transmission power, the different calling channel being selected to have an incrementally lower channel data rate and/or an incrementally higher channel transmission power.

The predetermined number of reply signals, which may be static or variable, is preferably calculated to correspond to a desired number of "neighbour" stations available to a given station as intermediate or destination stations, to permit the given station to communicate freely with other stations in the network without causing undue contention or interference between stations.

The method may further include defining a plurality of data channels, each data channel except the first having a higher data capacity than a previous data channel, each station transmitting data to neighbour stations on selected data channels after determining the availability of said neighbour stations.

The data channels preferably correspond to the calling channels, a data channel being selected for transmission of data which corresponds to the calling channel in use when the desired number of neighbour stations was established.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a multi-station communication network, indicating how an originating station can transmit data via a plurality of intermediate stations to a destination station; and

Figure 2 is a flow chart illustrating the operation of the channel adaptation and probing method of the invention.

DESCRIPTION OF AN EMBODIMENT

The network illustrated schematically in Figure 1 comprises a plurality of stations, each comprising a transceiver able to receive and transmit data from any other station within range. A communication network of this kind is described in PCT patent application no. PCT/GB 95/02972, the contents of which are incorporated herein by reference.

In Figure 1, an originating station A is able to communicate with five "nearby" stations B to F, and is transmitting data to a destination station O via intermediate stations B, I and M.

In order to maximise the efficiency of the network, it is desirable that each station should have a number of "neighbour" stations with which it can communicate, in case that station needs to send or receive a message. On the other hand, if a given station is transmitting data to a selected neighbour station, it is desirable that the transmission should cause the minimum of interference to other stations, otherwise the resulting contention between stations will reduce the amount of data throughput in the network.

With the above in mind, the present invention seeks to adjust the operation of each station so that it can at any time send data to or receive data from a number of neighbour stations, at the highest possible data rate but at the lowest possible transmitted power, thus reducing interference with other stations.

A communication network of the abovementioned kind comprises many stations trying to communicate on the same set of channels. The channels can be defined as having different frequencies, different media, different coding, different antennas, different time slots etc., or any combination of these. In order to optimise channel re-use, the invention provides for stations to try to maintain a limited number of immediate neighbours, typically 5 neighbours. A neighbour is defined as another station that a given station can communicate with.

A station can limit the number of neighbours it sees by changing its transmission frequency, changing code (PN Sequence), increasing its data rate, and dropping its transmit power. All stations will gather at predefined Calling Channels where they will find other stations to communicate with using a probe signal. Once another station is found and either of the stations

have data to send they may then move to a less used Data Channel.

When there are a number of stations in close proximity they will end up using high data rates and low transmit powers. Stations will occasionally check the lower data rate Calling Channels to help any distant stations that cannot use the higher data rates. In the same way a station that is on a lower data rate Calling Channel will occasionally check all the data rates above its current data rate in order to find possible clusters of high data rate stations.

The flow chart of Figure 2 shows how several different channel adaptation timers of the invention work in a given station. The flow diagram shows each of the timers being checked in sequence. However, they may be separate processes or events that are all checked simultaneously. The following sections will describe the different Channels and the associated Timers.

Probing - On Calling Channel

Each station will transmit probe signals at regular intervals (determined by a Probe Timer) trying to find other stations. Should any other station receive the probe it will randomly reply to the probe. The random reply would typically be 1 reply for every 1 to 4 probes received. This prevents contention with other stations in close proximity.

The time between probes set by the Probe Timer is used to respond to other stations for every 1 to 4 probes received. Since the time between probes is longer than the probe duration a replying station can respond with a small

data packet that also contains data. However the maximum length of the response packet may not be longer than the normal Probe Timer interval.

Each station will randomly vary the Probe Timer slightly between probe signal transmissions to avoid collision with other stations. Should any station start receiving another station's transmission, it will reload the Probe Timer with a new interval.

When a station has data to send it transmits probes at an interval proportional to the data rate it is using (Probe Timer 1). However if a station has no data to send it will use an interval typically 5 times longer (Probe Timer 2) than that used when it has data. This allows stations that have data to send more opportunity to communicate. Because other stations will reset their Probe Timer every time a transmission is detected they may never probe if they have no data to send. Therefore every station will force out a probe after at least five times the normal interval.

A station that has data to send will be transmitting probes five times as often as a station with no data. the station with no data will rest its Probe timer every time it hears the other station probe. Since the station with no data is using a longer interval it will never have a chance to transmit. therefore the station with no data will reset its Probe Timer each time it hears the other station, unless the last time it transmitted was longer ago than the Probe Timer 2 interval, in which case it will reset its Probe Timer to the Probe Timer 1 interval. The station with data will also be using an interval corresponding to Probe Timer 1, therefore the station without data will get a chance to send a probe out. After sending out the probe it will revert back to using a time interval of Probe Timer 2.

The probe sent out by a station with no data to send is addressed to all stations (Broadcast Probe). Therefore any station may respond. However if a station has data to send it will alternate its Broadcast Probes with probes addressed to stations for which it has data (Addressed Probe). The Addressed Probes will sequentially go through all the IDs for which a station has data. Only the station addressed by the Addressed Probe may respond. Since no other station will respond, the addressed station will always respond immediately.

Calling Channel Adaptation

After first switch-on a station will start probing at the lowest transmit power and fastest data rate (Highest Calling Channel). This is to avoid interfering with other stations that may be in close proximity.

Each time a different station replies to the probe, the replying station is counted as a neighbour. If the required number of neighbours is not met within a predefined time interval (set by an Adapt Timer) the station will then increase its probe transmission power by 10dB. It will continue to increase its probe transmit power until it achieves the required number of neighbours. If it reaches the maximum transmit power before reaching the required number of neighbours the station will then drop to the next data rate (Previous Calling Channel), but stay at the maximum transmit power. It will continue to drop its data rate until it achieves the required number of neighbours. If it never reaches the required number of neighbours it will remain at the lowest data rate and maximum transmit power.

Every time the station moves to a different Calling Channel it resets the Adapt Timer. It will also reset the Adapt Timer each time it changes its probe transmit power.

In a network of mobile stations the stations are constantly moving, and as such the number of neighbours will constantly be changing. If the number of neighbours exceeds the required number a station will start to increase its data rate (Next Calling Channel). It will continue to increase its data rate until it no longer exceeds the required number of neighbours. If it reaches the maximum data rate it will start to drop its probe transmit power by 10dB until it either reaches the minimum transmit power, or no longer exceeds the required number of neighbours.

Every time a station changes its data rate it will move to a different Calling Channel. This is to avoid the lower data rates interfering with the higher data rates.

Data Channel

When a station responds to another station on a Calling Channel it will limit the length of its data packet to the Probe Timer interval. This is to avoid other stations probing over its reply. If the station that is replying has more data to send than will fit in a small packet it will indicate in the header of the packet that the other station must move to a specific Data Channel.

There can be a number of Data Channels defined for each Calling Channel. The station that is requesting the change will randomly select one of the available Data Channels. When the other station receives the request it will

immediately change to that Data Channel where the two stations will continue to communicate until neither of them have any data to send, or if the maximum time for remaining on the Data Channel expires (set by a Data Timer).

When a station changes to the Data Channel it loads the Data Timer. It will remain on the Data Channel for as long as the Data Timer will allow. When the Data Timer expires the stations will revert back to the Calling Channel and start probing again.

Check Channel

For each Calling Channel there is a Previous and Next Calling Channel, except for the lowest data rate Calling Channel that only has a next Calling Channel, and the highest data rate Calling Channel that only has a previous Calling Channel. As the number of neighbours in an area increases, the stations will move to higher data rate Calling Channels. However stations that are further from the area will not have as many neighbours and therefore will remain on the lower data rate Calling Channels. In order for the stations to remain in contact, the stations must check the previous and next Calling Channels at regular intervals.

A Check Timer is set when a station arrives on a Calling Channel for the first time. The Check Timer period is proportional to the data rate of each Calling Channel (Check Timer 1). When the Check Timer expires the station first determines if it is currently checking or if it must still check. If it were checking it would drop to the previous Calling Channel from the one it was checking. However if it was not checking the station would jump

to the Highest Calling Channel. This channel becomes the current Check Channel.

When a station arrives at a Check Channel it will reset the Check Timer. The Check Timer (Check Timer 2) period will be a much shorter interval than was used when arriving on a Calling Channel. After the Check Timer expires the station will then move down to the Previous Calling Channel. This then becomes the new Check Channel.

The station will continue in that manner until it reaches the original Calling Channel. At this point it drops one channel below the Calling Channel. If there is no previous Calling Channel it will terminate the checking and reset the Check Timer to the longer value (Check Timer 1). If there were a Calling Channel it would repeat the normal check operation. After this last check it will revert back to the original Calling Channel.

This means that a station will periodically check all Calling Channels above its current Calling Channel and one channel below its current Calling Channel. It will take a small amount of time to check the upper channels since they would typically be working at a rate 10 times faster than the current channel. However it will take time to check the Calling Channels below the current one, and it is for this reason that it only checks one level down.

Checking the Calling Channels not only keeps stations on different Calling Channels in contact, it also helps stations on lower Calling Channels to see more neighbours and therefore help them move up to the higher Calling Channels.

Timer Multiplication Factors

For each Calling Channel the data rate would typically be 10 times higher than the previous Calling Channel. From the data rate of the Calling Channel the duration of all the timers can be calculated using multiplication factors. The absolute values of the factors are given below, but it should be noted that these values are given as examples and may vary quite significantly. In addition, the correct values may be dynamically changed as the network traffic load and number of stations changes.

Timer	Multiplication Factor	8k rate example
Probe Timer 1:	10 x duration of Probe Packet (Data in Tx Queue)	300 msecs
Probe Timer 2:	5 x Probe Timer 1 (No Data in Tx Queue)	1500 msecs
Adapt Timer:	100 x Probe Timer 1	30000 msecs
Data Timer:	5 x Probe Timer 1	1500 msecs
Check Timer 1:	30 x Probe Timer 1 (Not currently checking)	9000 msecs
Check Timer 2:	2 x Probe Timer 1 of current Check Channel	60 msecs (80k check)

Additional Points on Channel Use

The following constraints/options will typically be implemented in a network using the method of the invention:

* A station may never communicate at a data rate less than the data rate of the Current Channel, however it may communicate at a higher data rate if the bandwidth allows.

* A station will never respond to another station whose received S/N ratio falls below the required level. However if there is no Previous Channel to fall back to it will respond. For example, if it is on an 80 kbps channel, it will not respond to a station whose received S/N ratio is bad. This will force the other station to fall back to 8 kbps. However if it is already at 8 kbps, then there is no other channel to fall back to and it therefore will respond.

* When switching channels a station must always wait for the duration of the Probe Timer before probing so that its probe signals do not collide with transmissions from other stations.

* When responding to a station, the length of the packet will always be less than the Probe Timer delay, to prevent hidden terminals breaking response packets. When station A responds to a probe from station B on the calling channel, the length of the response packet, measured in time, will be less than the Prober Timer 1 interval. This is to prevent a third station C from transmitting over the response packet. This can happen when station A and station C can hear each other but station B and station C cannot hear each other. Station C would reset its probe interval when it detects station A sending out a probe. Since it cannot hear station B, it will not reset its probe interval when station B responds. therefore it would send out a probe after the Probe Timer expires. The probe from station C would corrupt the response packet from station B if it was longer than the Prober Timer. However, if the response packet is shorter it would reach station A without corruption before station C sends out a probe.

* If a station has more data to send than can be sent within the Probe Timer interval, then the station will send what it can, and it will request that the other station change to a Data Channel. Therefore two stations should not communicate more than three "overs" (ie. consecutive replying transmissions) on the Calling Channel. Eg. station 1 Tx Probe -> station 2 Tx Data -> station 1 Tx Data (Either station 1 Tx Data, or station 2 Tx Data will request a Data Channel if they have more data to send).

* The Probe Timer interval will not always be the same, it will have a random variation added to it (typically 50% of the Interval Timer duration). This will prevent a number of stations all transmitting at the same time each time, and thereby never receiving each other. For example, at 8 kbps the Probe Timer (With Data in Tx Queue) would typically vary between 300 and 450 milliseconds.

* When a station has no data to send it will try to acquire five neighbours. However when it has data it may then choose to try to acquire more neighbours (typically 15). It should be noted that the station would be probing at a faster rate and therefore more likely to acquire more neighbours. If it does not acquire more neighbours it may then increase its transmit power. It should be noted that in networks with a heavy traffic load the number of neighbours required may not be increased as this would cause excessive contention.

* Stations can keep track of other stations moving to Data Channels. This will give an indication as to which data channels are available.

* A second receiver can be used to scan Data Channels to find clear Data Channels with good background noise.

* When a station probes it can provide information in the header of its probe signal data packet as to which Data Channels it monitors as clear. When another station responds and wishes to change to a Data Channel it can then combine its own information with that of the other station to make a better choice as to which Data Channel to use.

* When a station is sending data it must not use a power level much higher than the power used for probing. For example, if a station is probing at OdBm to achieve the required number of neighbours then it must not respond with power at, say, 30dBm as this would interfere with other stations further away. (The amount by which the power used for the transmission of data may exceed the probe power will be a parameter set for the entire network).

* Noise and traffic can be monitored on multiple Calling and Data Channels simultaneously, using multiple receivers.

* Probe and Data packets can be transmitted on multiple Calling and Data Channels simultaneously, using multiple transmitters.

* The network may have more than one Calling Channel per data rate and many Data Channels per data rate.

In an alternative embodiment, the invention makes use of two types of probe signals. The first type of probe signal is a Broadcast Probe that contains a list of the best stations that a given station can detect. The number of stations in the list is typically in the order of 10. Associated with each station in the list is a number that indicates how well the probing station heard the ones in the list. Another number would indicate how well the stations in the list detected the probing station (this is gathered from the other stations' Broadcast Probes). Thus a third station will immediately know how well the probing station heard another station and how well the other station heard the probing station.

This arrangement eliminates the need to respond to probes, since when a station hears its own ID in a probe it knows that the probing station can hear it, and how well. When it then sends out its own probe, it will include the ID of the station that it has just heard. The other station will hear its own ID, thus closing the loop. Therefore by just sending out probes any station in close proximity with others will know which stations can hear it, and how well. It will also know by monitoring the other Probes which other stations the one probing can detect and how well. This information will then be used to set the number of neighbours.

Each Broadcast Probe from each station contains a list of all the stations it has detected. Since all the stations that can hear the probe will see themselves in the list, the station sending the probes does not need to do as often. In the method of probing described in the first embodiment above, a station needed to get a response from every other station in order to know they could hear it. Now all the neighbouring stations will know that the probing station can hear them since they appear in the list. When they in

turn send out Broadcast Probe all the other stations will now they have been heard if they appear in the list.

The second type of probe signal of this embodiment is the Addressed Probe. When a station has data to send to or via a second station it will insert Addressed Probes between its Broadcast Probes at a much higher repetition rate. These Addressed Probes will force the addressed station to respond. Thus, when it has data to send the station will send a short Addressed Probe at faster intervals, thus increasing the opportunity to connect to the required station. The addressed station knows the probing station has data to send, otherwise it would not be addressing it. The addressed station may then chose to move to a Data Channel where the two stations will transfer data.

If a station does not see its own ID in the Probe List, and the list is not full, it should then randomly respond to the station sending the probe at the power level required to get back to the station in question. (This is to prevent a distant station never seeing any neighbours as they will all be probing at a lower power level.)

The Addressed Probe from any station will also include a list of the stations from which it received data, that it will send to the address station. For each station ID in the list there will be a number indicating how old the data in question is. Thus any other station listening to the probe will know that it has a route back to the source of the data (Origin) and will know how long it took the data to reach it. This information can then be used for routing.

If a station hears two different stations sending Addressed Probes with the same Origin ID, but different message delay times, then it can determine

which is the shorter, and thus a better route. This will provide a gradient toward the Origin ID. When a station wishes to reach the Origin ID it will use this information to route the segments. If conditions change the station will dynamically re-route the segments in question.

A station will always know what power is required to get back to another station. Therefore it will know what power to use so that its probes will be heard by all its neighbours. For example, if a station is trying to achieve five neighbours it will probe at the power required to reach all five of the closest neighbours. In the first method of probing described above the station would simply increase its power in 10 dB steps until the required number of neighbours was met. However, because it is using 10 dB steps, it may well exceed the required number of neighbours. It would then drop its power by 10 dB and then be below the required number. What will happen now is that the station knows that if it drops another 10 dB it will lose its required number of neighbours. Instead the station will work out what power it must probe at so that it will reach the required number neighbours, and will not go below this power even if the required number is exceeded. It should be noted that the required power will always be changing as the conditions change.

A station will try to keep a minimum number of direct and indirect neighbours. If for example it is trying to keep one direct neighbour and at least 5 indirect and direct it will work out the power required to reach the direct neighbour. If through this one neighbour it can reach another 4 neighbours then it has achieved its 5 direct and indirect neighbours. Otherwise it would use a higher power that may include 2 direct and 7 indirect, as long as it does not have less than the required number.

Part of the demodulation process at any station includes forward error correction. If the forward error corrector detects irrecoverable errors during the reception of a packet it can notify the main code that an error has occurred. The main code can then abort receiving the packet. This will prevent a station being tied up receiving a packet that is corrupt. It can also assist the station in receiving another packet from another station sooner. Sometimes in a network of the kind in question, one station will transmit at a higher level than another station, thereby corrupting the packet. It would be possible for the receiving station to detect the corrupted packet, abort reception and start receiving the stronger signal.

DATED THIS 6TH DAY OF JUNE 1997

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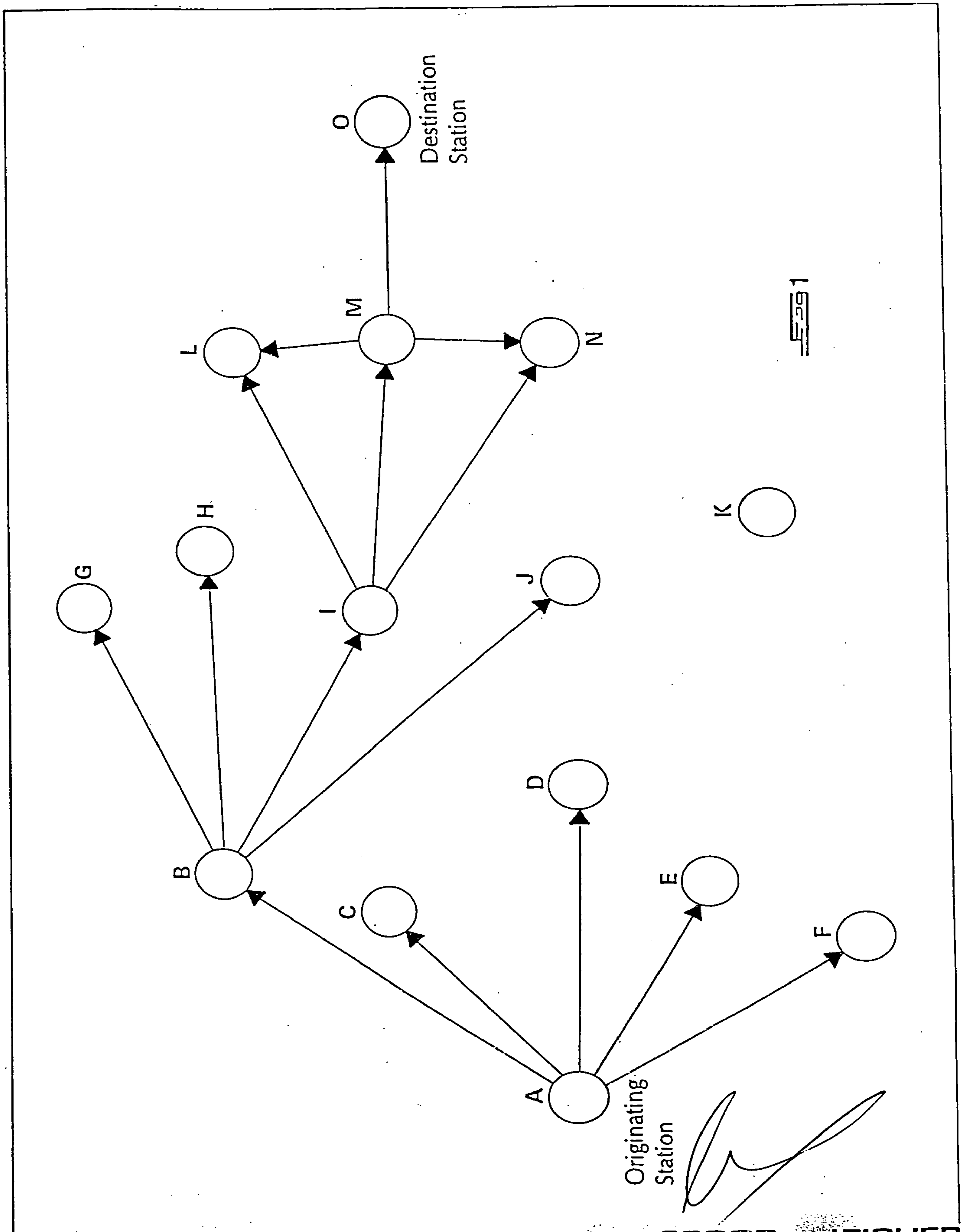

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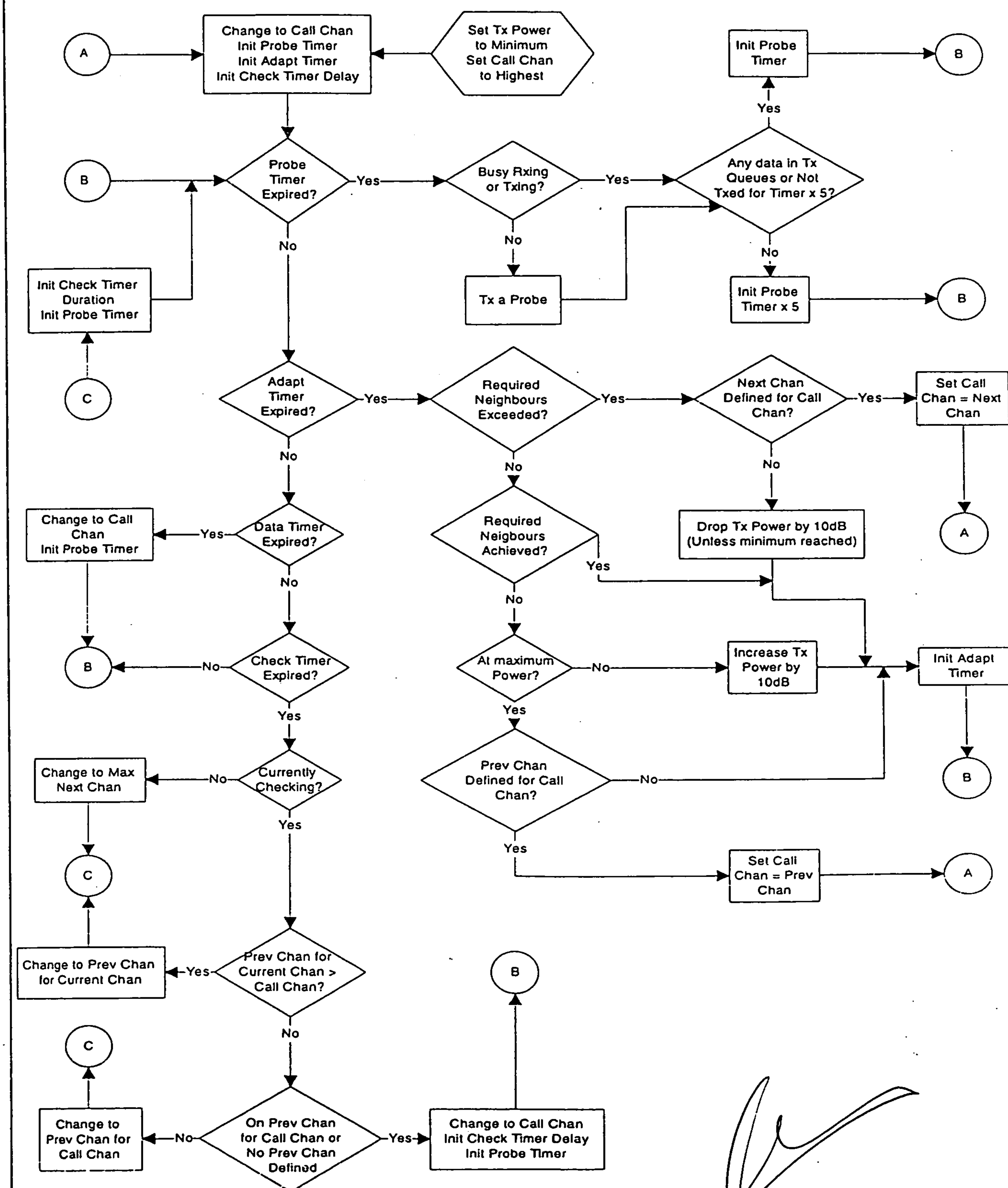
FIG 2



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